SUNSHINE-CLOUDINESS RELATIONSHIPS IN THE UNITED STATES

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ABSTRACT

The statistical treatment of areal and seasonal groupings of mean annual and mean monthly percentage sunshine and percentage cloudiness data for United States stations based on relative amounts of stratiform cloudiness yields interesting and useful results. These results are readily apparent in charts which have been developed to depict the regression lines, errors of estimate, and coefficients of correlation, and which are included in this article. For example, the charts reveal that the regression line for the relatively low percentage sunshine months for the areas of the country with high amounts of stratiform cloudiness is well displaced from that for the relatively low percentage sunshine months for areas with comparatively low amounts of stratiform cloudiness.

1. INTRODUCTION

The amount and nature of the cloudiness prevailing at a location within any interval or the whole of the period of the day between sunrise and sunset are primary factors in determining the percentage of possible sunshine received. Since records of the observed amounts and nature of cloudiness and their monthly and annual mean values are available for many more localities than are records of percentage of possible sunshine, reliable formulae for expressing the latter in terms of the amount and nature of cloudiness are useful in climatological work. However, few results of studies to relate both the amount and nature of the cloudiness prevailing over large areas to the percentage of possible sunshine received appear to be available.

The maps for average annual number of days with dense fog, percentage of possible sunshine winter and summer, and average number of cloudy days per year appearing in [1] depict information which, when compared, reveal the interrelation of sunshine and the amount and the nature of cloudiness in a general fashion. These show that the regions in the contiguous United States having low percentages of possible sunshine (namely, the narrow band along the North Pacific coast, the Great Lakes region, and the large area to the east and northeast of the Gulf of Mexico) have a high incidence of cloudy days and days with fog. They also reveal, conversely, that the regions with high percentages of possible sunshine (the area from the Coastal Ranges of the west eastward into western and northern Texas, Arkansas, and the middle and upper Mississippi Valley) in general experience a lower incidence of cloudy days and days with fog.

Byers [2] has pointed out that, except for points at higher mountain elevations, fog is really a stratus cloud cover at or close to the ground. It does not necessarily follow that each weather station away from mountaintops having a high incidence of foggy days also reports more stratiform cloudiness than does every station having a low number of foggy days in the year. However, most weather stations in the more foggy regions of the contiguous United States report more stratiform cloudiness than do those in the less foggy ones. Thus, it may be broadly stated that the narrow strip of land between the Pacific Ocean and the western Coastal Ranges, the Great Lakes region, and the area to the east and northeast of the Gulf of Mexico are characterized by more stratiform cloudiness than are the other areas in this part of the globe.

Landsberg [3] points out that the percentage of sunshine plus the percentage of cloudiness equals 100 as a first approximation. Some studies, both for points in the United States and elsewhere, have been made to determine this relationship more precisely. However, except for the reports by Sternes [4] [5], there is no record of a comprehensive study of this relationship for the United States using recent data.

The table of normals, means, and extremes for some United States localities [6] provides recent "period of record" data for mean monthly and annual percentages of possible sunshine and mean monthly and annual sky cover sunrise to sunset. These cloudiness values may be expressed in percentages and readily compared with percentage of possible sunshine values to determine their interrelation. Though most of the localities for which these data are prepared do provide mean sky cover values, many do not maintain records of percentage of possible sunshine or have these records only for extremely short periods. Only 132 weather stations reported "period of record" values for both percentage of possible sunshine and mean sky cover sunrise to sunset for at least 12 years in their 1958 annual issue [6]. These were selected for this study. The percentage cloudiness data

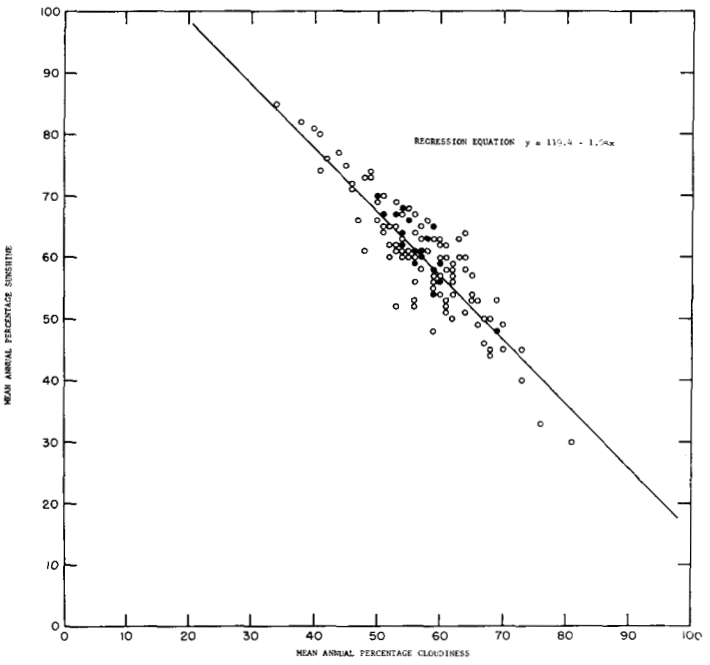

FIGURE 1.—Mean annual percentage cloudiness vs. mean annual percentage sunshine for 132 stations in the contiguous United States and Alaska. See figure 2 for locations. Filled circles represent data for more than one station.

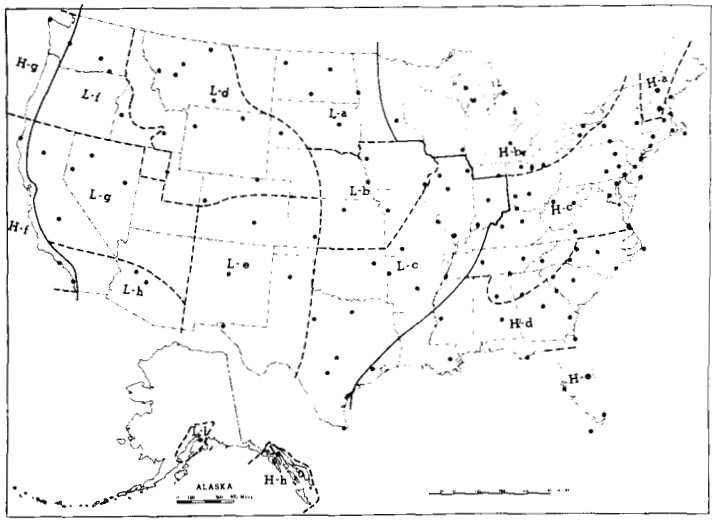

FIGURE 2.—Areas of the country with relatively high (H) and relatively low (L) amounts of stratiform cloudiness and sub-areas within which stations tend to have the same months of the year with relatively high, relatively low, and near average mean monthly percentage sunshine with respect to mean monthly percentage cloudiness. See table 1 for grouping of months for the sub-areas.

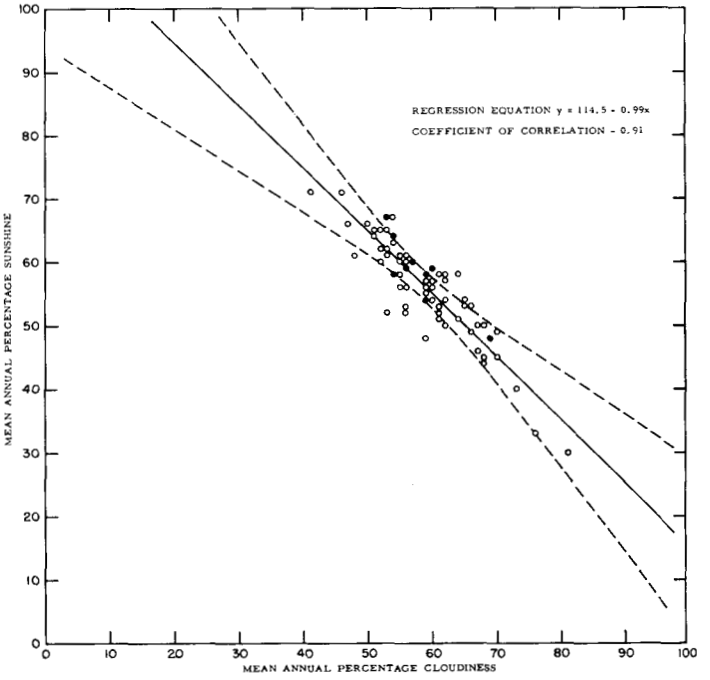

FIGURE 3.—Mean annual percentage cloudiness vs. mean annual percentage sunshine for 75 stations with relatively high amounts of stratiform cloudiness. Filled circles represent data for more than one station. Dashed lines delineate area within which the true regression line lies, for odds of 95 to 5.

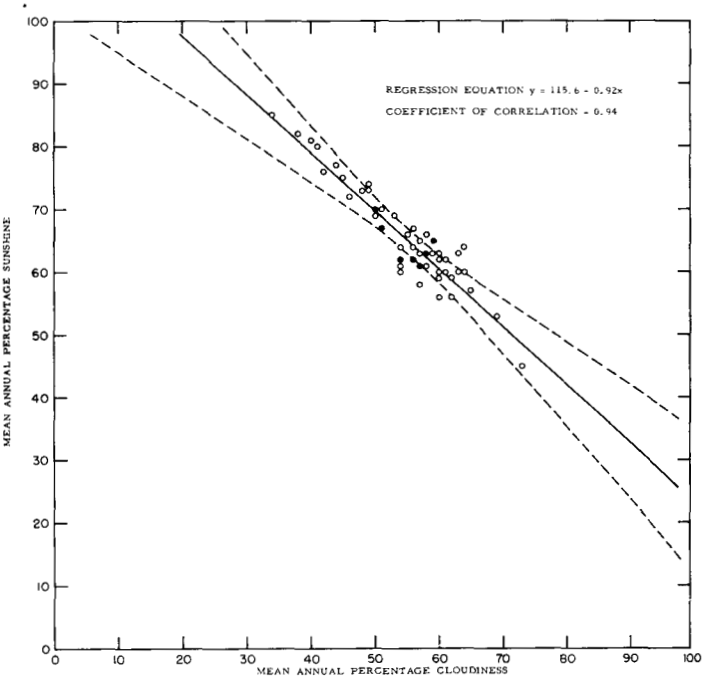

FIGURE 4.—Mean annual percentage cloudiness vs. mean annual percentage sunshine for 57 stations with relatively low amounts of stratiform cloudiness. See legend to figure 3.

were converted from their values for mean sky cover reported to tenths.

Examination of the annual values for these 132 stations indicated that Sternes' regression line for the annual data underestimated most of the values for the stations in the portions of the country with generally less cloudiness and/or lesser amounts of dense cloudiness, and that his regression line tended to overestimate values for stations in the more humid, cloudier portions of the country. This suggested not only developing regression equations by geographic areas for the mean annual data based

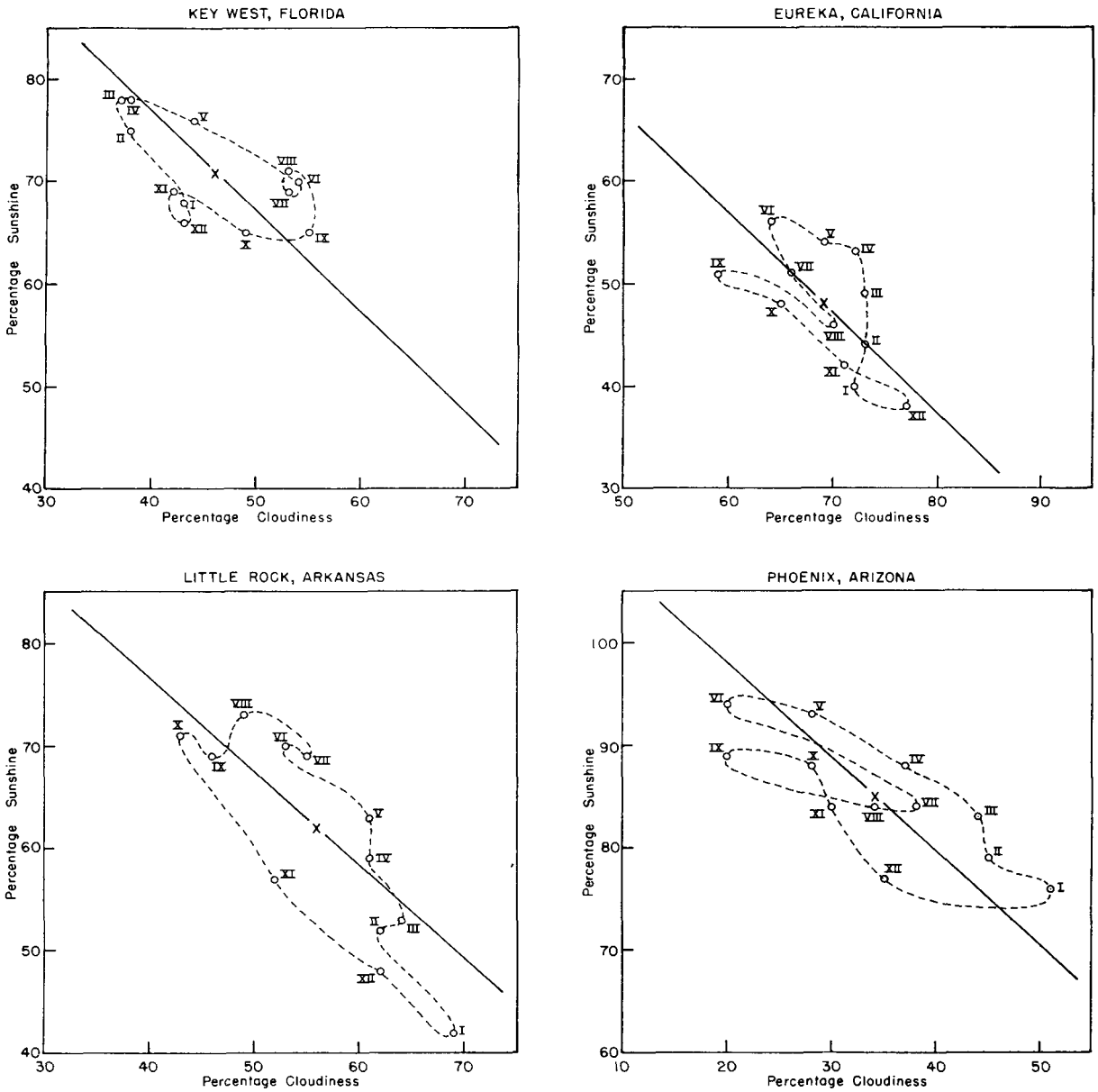

FIGURE 5.—Climographs for mean monthly percentage cloudiness vs. mean monthly percentage sunshine for 2 stations (top) in areas with relatively high amounts of stratiform cloudiness and 2 stations (bottom) in areas with relatively low amounts of stratiform cloudiness. Point indicated by x shows mean annual value and solid line is parallel to the regression line for all stations in that particular type of area. See figures 3 and 4.

on general density of cloudiness considerations, but also grouping the months of the year on the basis of cloudiness and/or density of cloudiness for determining shorter-period relationships. This is the course taken in this study.

2. ANNUAL DATA RELATIONSHIPS

The mean annual percentage sunshine and the mean annual percentage cloudiness for the 132 United States stations were studied to determine their relationship. The plot of these values appearing in figure 1 shows that the equation, percentage sunshine plus percentage cloudiness equals 119, gives a fairly close approximation. However, there is considerable scatter about the regression line determined from these data.

Grouping on a basis of amounts of dense cloudiness with the country divided as shown by the solid lines in figure 2, resulted in data for 57 stations being available for studying the sunshine-cloudiness relationship for the portion of the country with relatively low amounts of stratiform (dense) clouds. Data for the remaining 75 stations were then used for studying this relationship for the parts of the country characterized, in general, by having more stratiform (dense) cloudiness.

Figures 3 and 4 show this relationship for the two sets

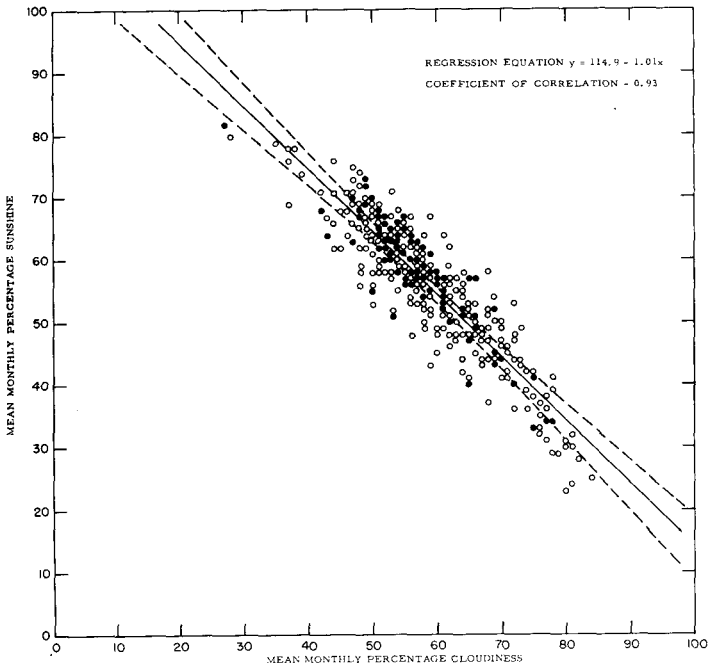

FIGURE 6.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the areas with relatively high amounts of stratiform cloudiness in which the sunshine is near average with respect to the cloudiness. See legend to figure 3.

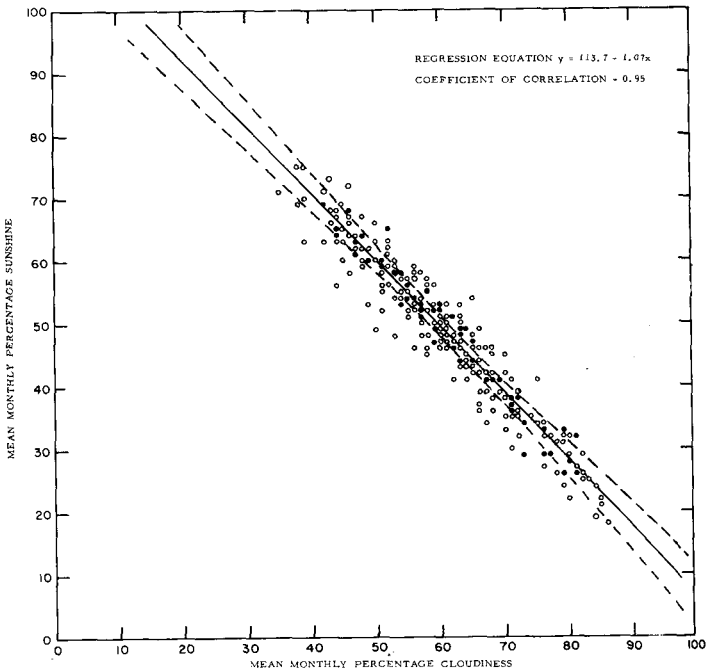

FIGURE 8.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the areas with relatively high amounts of stratiform cloudiness in which the sunshine is relatively low with respect to the cloudiness. See legend to figure 3.

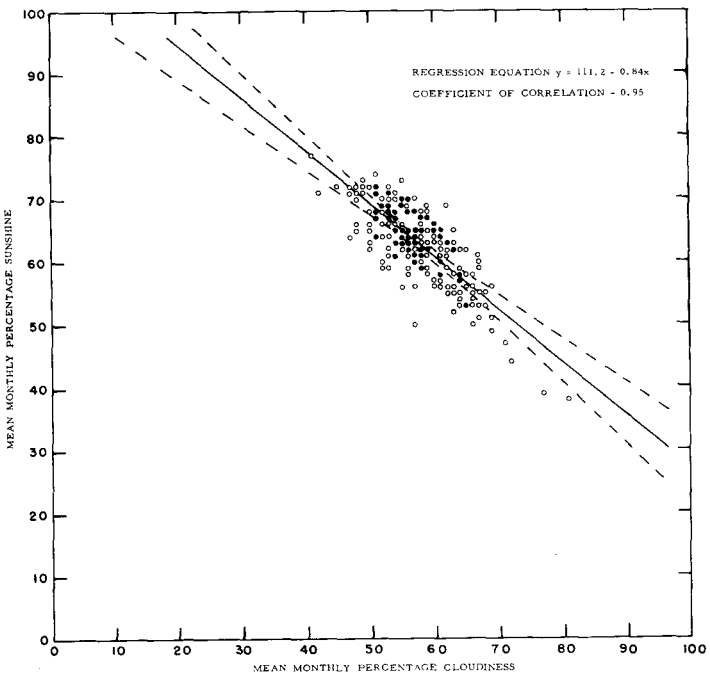

FIGURE 7.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the areas with relatively high amounts of stratiform cloudiness in which the sunshine is relatively high with respect to cloudiness. See legend to figure 3.

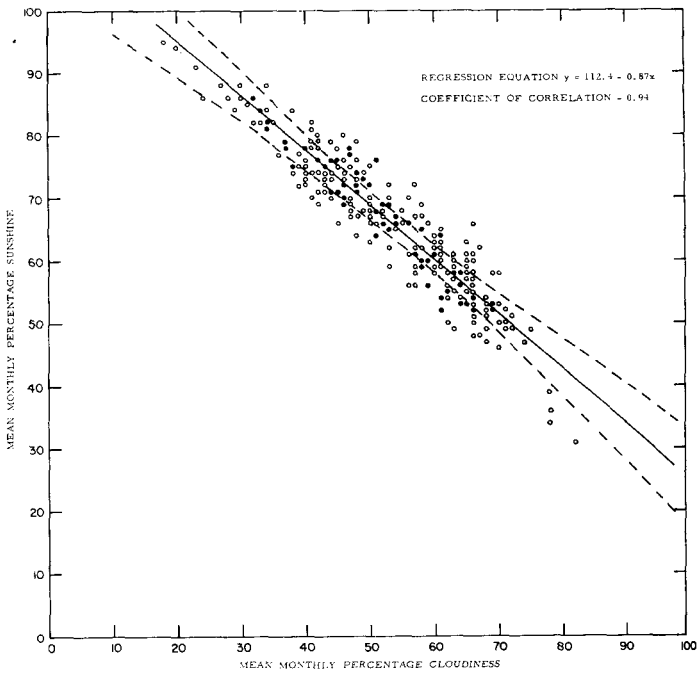

FIGURE 9.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the areas with relatively low amounts of stratiform cloudiness in which the sunshine is near average with respect to the cloudiness. See legend to figure 3.

of data and reveal much less scattering of points than for the data for the 132 stations combined. Also depicted is the higher values of percentage sunshine for given values of percentage cloudiness for the stations in the areas having less stratiform cloudiness and also the lower rate of increase of percentage sunshine with decrease in percentage cloudiness for these stations and vice versa.

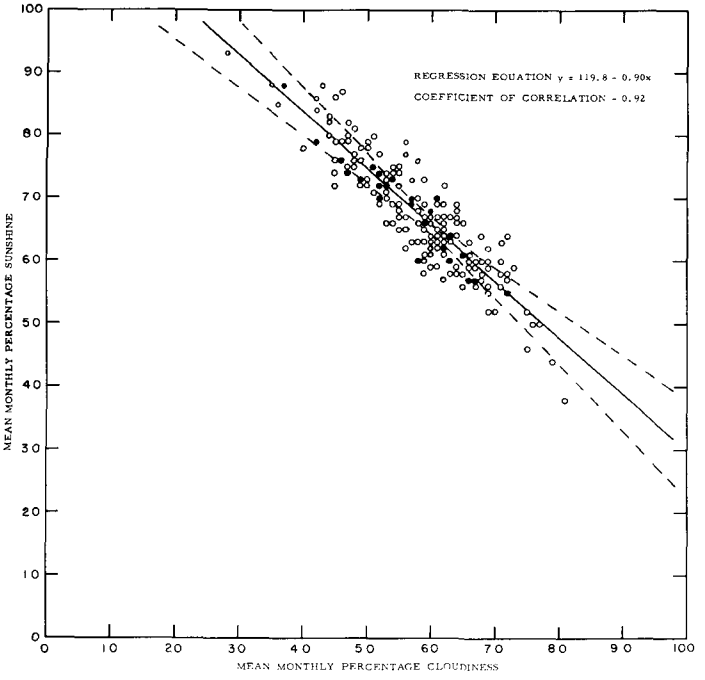

FIGURE 10.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the area with relatively low amounts of stratiform cloudiness in which the sunshine is relatively high with respect to cloudiness. See legend to figure 3.

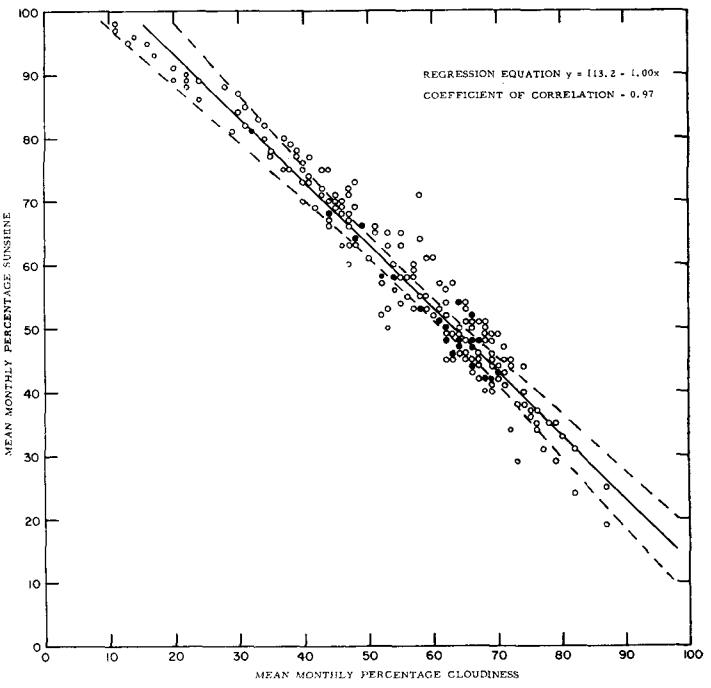

FIGURE 11.—Mean monthly percentage cloudiness vs. mean monthly percentage sunshine for the cases for the areas with relatively low amounts of stratiform cloudiness in which the sunshine is relatively low with respect to the cloudiness. See legend to figure 3.

3. MONTHLY DATA RELATIONSHIPS

Reference to climographs for two widely separated stations having relatively high amounts of stratiform cloudiness, Key West, Fla. and Eureka, Calif., and for two widely separated stations having relatively low amounts of stratiform cloudiness, Little Rock, Ark. and Phoenix, Ariz. (see fig. 5) provides a hint as to the dispersion which would result if all the monthly values for all the relatively high stratiform cloudiness stations were treated together and, correspondingly, all the monthly values for all the relatively low stratiform cloudiness stations were treated together. It also is evident from these climographs that it would be unwise to consider studies of January data separately, February data separately, and so on, since not all the areas with relatively high amounts of stratiform cloudiness have their periods of high percentage cloudiness-low percentage sunshine (and vice versa) concurrently. The same is true for portions of the relatively low stratiform cloudiness areas.

Accordingly, it was decided to consider the monthly values within the two area groupings with respect to whether the percentage of sunshine was low, about average, or high in relation to percentage cloudiness. This was done with each month's data separately for each station in each of the two categories. The procedure was to ascertain whether each monthly value for the station fell within, was outside and above, or outside and below the area determined by the standard error of estimate value reported in figures 3 and 4 when considered with respect to a line parallel to the originally determined regression curve for the sample of stations and passing through the plot of the annual percentage sunshine and percentage cloudiness values for that station (see fig. 5). This placed a reasonable size sample in each of the three sets of data for each of the two types of areas.

This treatment of the data for the stations within various distinct geographical sections of the country revealed that usually about the same set of months had about average, above average, and below average monthly percentage sunshine, respectively, in relation to percentage cloudiness. The monthly data were then arrayed with respect to this qualitative relationship as shown in table 1 and treated to obtain the regression lines, coefficients of correlation, and errors of estimate depicted in figures 6–11. The regression equations are collected in table 2.

Most of the error of estimate values obtained by this procedure are relatively low as revealed in these figures. The regression line for the relatively low percentage sunshine months for the areas of the country with relatively high amounts of stratiform cloudiness is well displaced from that for the relatively low percentage sunshine months for the areas with comparatively low amounts of stratiform cloudiness and far removed from the regression line for the relatively high sunshine months for the latter areas.

TABLE 1.—*Months with relatively high (+), relatively moderate (○), and relatively low (−) values of mean percentage sunshine with respect to values of mean percentage cloudiness for different regions of the United States.*

	J	F	M	A	M	J	J	A	S	O	N	D
H. Areas with Relatively High Amounts of Stratiform Cloudiness												
a. Higher regions of Maine, New Hampshire and Vermont*	○	○	○	○	○	○	○	○	○	○	○	○
b. Great Lakes region including all of Wisconsin and eastern Minnesota	−	○	○	+	+	+	+	○	○	−	−	−
c. Middle eastern and northeastern regions excluding the higher elevation of the far Northeast	−	○	○	○	+	+	+	○	○	−	−	−
d. Southeastern region excluding Florida Peninsula	−	○	○	○	+	+	+	+	○	−	−	−
e. Florida Peninsula*	−	−	○	○	○	+	+	+	○	○	−	−
f. California coastal area*	○	○	○	○	○	○	○	○	○	○	○	○
g. Washington and Oregon coastal area*	−	○	○	+	+	○	○	○	○	○	−	−
h. Southeastern Alaska*	○	○	+	+	○	○	○	○	○	−	−	−
L. Areas with Relatively Low Amounts of Stratiform Cloudiness												
a. North Central region	○	○	+	+	+	○	○	○	○	○	−	−
b. West Central region	−	○	○	○	+	+	+	○	○	−	−	−
c. South Central and East Central regions	−	−	○	○	+	+	+	+	○	−	−	−
d. Northern Rocky Mountain and High Plains regions	○	+	+	+	+	○	○	○	○	−	−	−
e. Southern Rocky Mountain and High Plains regions	○	○	○	+	○	○	○	○	−	−	○	○
f. Cascade Range and northern Plateau regions	−	○	+	+	+	+	○	○	○	○	−	−
g. Sierra Range, San Joaquin Valley, and central Plateau regions	○	○	+	+	+	○	−	−	−	−	○	○
h. Interior Southern California* and southern Plateau regions	○	+	+	+	+	○	○	○	−	−	−	−
i. Cook Inlet Area-Alaska*	−	○	+	+	+	+	+	○	○	−	−	−

*Includes data for fewer than five stations.

4. CONCLUDING REMARKS

This study presents the procedures used and some of the results obtained in determining the relationship between percentage sunshine and percentage cloudiness for United States stations through areal and seasonal groupings of the mean annual and mean monthly data based on relative amounts of stratiform cloudiness. The groupings are by areas for the mean annual and mean monthly data and, further, by portions of the year for the latter.

These treatments of the mean annual and mean monthly percentage sunshine and percentage cloudiness for recent years for United States stations provide realistic and usable measures of the interrelation of these data. Table 2 summarizes these relations.

TABLE 2.—*Equations for interrelation of percentage cloudiness and percentage sunshine. Refer to table 1 for key to the portions of the year covered by each category for the various parts of the country. y is mean percentage sunshine; x is mean percentage cloudiness, sunrise to sunset; and $\overline{S}$ is standard error of estimate.*

H. In Areas with Relatively High Amounts of Stratiform Cloudiness		
a. For mean annual values. (fig. 3)	$y=114.5-0.99x$	$\overline{S}=3.36$
b. For mean monthly values for portion(s) of year with highest amounts of stratiform cloudiness. (fig. 8)	$y=113.7-1.07x$	$\overline{S}=3.51$
c. For mean monthly values for portion(s) of year with lowest amounts of stratiform cloudiness. (fig. 7)	$y=111.2-0.84x$	$\overline{S}=3.87$
d. For mean monthly values for portion(s) of year not included in (b) or (c). (fig. 6)	$y=114.9-1.01x$	$\overline{S}=4.58$
L. In Areas with Relatively Lower Amounts of Stratiform Cloudiness		
a. For mean annual values. (fig. 4)	$y=115.6-0.92x$	$\overline{S}=2.70$
b. For mean monthly values for portion(s) of year with highest amounts of stratiform cloudiness. (fig. 11)	$y=113.2-1.00x$	$\overline{S}=3.53$
c. For mean monthly values for portion(s) of year with lowest amounts of stratiform cloudiness. (fig. 10)	$y=119.8-0.90x$	$\overline{S}=3.74$
d. For mean monthly values for portion(s) of year not included in (b) and (c). (fig. 9)	$y=112.4-0.87x$	$\overline{S}=3.77$

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